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Understanding the influence of nm-scale titanomagnetite on bubble nucleation in crystal poor rhyolite using 1-atm crystallization and vesiculation experiments

KELLY N MCCARTNEY[1], PROF. JULIA HAMMER, PHD[2], TOM SHEA[3], STEFANIE BRACHFELD[4] AND THOMAS GIACHETTI[5]

[1]University of Hawai`i at Manoa
[2]University of Hawai‘i
[3]University of Hawai'i at Mānoa
[4]Earth and Environmental Studies, Montclair State University
[5]University of Oregon

Presenting Author: kmccartn@hawaii.edu

Abundant small titanomagnetite particles, on the edge and/or below conventional observation methods, may be responsible for the heterogenous nucleation of bubbles in crystal-poor systems. Prior experimental studies revealed that bubble number densities (BND) are higher in the presence of such particles, which is important because eruption style is influenced by the BND [1;2]. Compared with microlites, nanolites have higher surface curvature, higher surface area to volume ratio, and thus higher specific interfacial energy. Heterogeneous bubble nucleation may be progressively enhanced as titanomagnetite particle size decreases.

This study combines controlled atmosphere experiments and magnetic analysis [3] to (a) modulate and characterize the titanomagnetite particle size and number density (TND) in obsidian produced by the 1100 CE Glass Mountain eruption (Medicine Lake, California, USA, 73.5 wt% SiO_2, 0.1 wt% H_2O), and (b) evaluate the influence of TND on BND. Obsidian was cored into cylinders (3mm diameter, 7-10mm length) and heated to 850˚C at fO_2 corresponding to ~QFM-1. Charges were held at these conditions for 6, 24, 48, and 72 h. A second set of experiments exposed identical obsidian cores to the same 850˚C dwell periods and subsequently exposed them to a second dwell at 1000˚C to stimulate H_2O exsolution and bubble nucleation. Magnetic characterization of all run products includes magnetic susceptibility, anhysteretic remanent magnetization, and hysteresis measurements.

We observe a near linear increase in bulk susceptibility (R^2=0.93) with 850˚C dwell duration, indicating a net increase in magnetic material. The ferromagnetic susceptibility to saturation magnetization ratio ($_f/M_s$), which is sensitive to changes in superparamagnetic content, decreases with treatment time, indicating a decrease in superparamagnetic abundance as nm-scale magnetic particles texturally coarsen. These observations suggest coarsening and increase of total magnetic material volume occurred. The BND of the second set of experimental run products (to be determined via computed x-ray tomography) will reveal whether grain size and number density influence bubble nucleation.

[1] Caceres et. al, 2020, The Geological Society of America, v. 48, pg. 997-1001.

[2] Caceres et. al, 2022, Earth and Planetary Science Letters, v. 577, pg. 1-11.

[3] Worm et al. (1999), Journal of Geophysical Research, v. 104, pg. 25415-25425.